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## C-A OPERATIONS PROCEDURES MANUAL

### 14.13 C-A EMS Process Assessment for Beam Stops & Collimators

Text Pages 2 through 16

#### Hand Processed Changes

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Approved:                     *Signature on File*                     \_\_\_\_\_  
 Collider-Accelerator Department Chairman                      Date

R. Karol

**BROOKHAVEN NATIONAL LABORATORY  
PROCESS ASSESSMENT FORM**

**I. General Information**

Process ID:	CAD-580-BMS	PEP ID# 580		
Process Name:	Beam Stops/Beam Collimators			
Process Flow Diagrams:	<a href="#">CAD-580-BMS-01</a>			
Process Description:	<p>The Collider-Accelerator Department operates several radiation-producing research facilities. Five of them, the Linac, Booster, Alternating Gradient Synchrotron, Relativistic Heavy Ion Collider and the National Space Radiation Laboratory utilize beam stops to absorb particle beams once they have served their useful research purpose. In the process of having their energy dissipated, these particles can create secondary radiation capable of producing radioactive species in surrounding material. Soil and air may become activated as a result. Beam collimators can create similar soil and air activation. If left uncontrolled, precipitation percolating through such activated soils can leach radionuclides into the water table. Air releases of radiation are insignificant.</p> <p>Applicable Subject Areas include: Radioactive Airborne Emissions, Environmental Monitoring and Pollution Prevention.</p>			
Dept./Div.:	Collider-Accelerator Department			
Dept. Code:	C-AD			
Building(s):	AGS Ring, Bldgs. 912, 914, Booster Ring, g-2 Beam Stop, RHIC Ring and NSRL.			
Room(s):	N/A			
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## II. Detailed Process Descriptions and Waste Determination

Located in the north central portion of BNL, the Collider-Accelerator Department is composed of several accelerator physics machines including the Linac, Booster, Alternating Gradient Synchrotron (AGS), the National Space Radiation Laboratory (NSRL), and the Relativistic Heavy Ion Collider (RHIC). The Linac/Booster/AGS is utilized to produce or accelerate high-energy protons, polarized protons; the Tandem/Booster/AGS/RHIC is utilized to produce or accelerate heavy ions for use in various experiments developed to study the fundamental characteristics of matter; the Tandem/Linac/Booster/NSRL is utilized to produce protons or heavy ions for research in the diverse field of biological effects and materials studies. The AGS complex is composed of a ½-mile circumference accelerator ring, a smaller 1/8-mile circumference booster ring and a linear accelerator. Particles are accelerated within the AGS ring and then directed via one of the four primary beamlines to various experimental beamlines and targets. The NSRL, located north of the Booster, is used to supply ions ranging from protons up to gold for radiobiology and material studies by NASA. RHIC is a 2.4-mile circumference particle accelerator/collider. The RHIC facility consists of a beam injection system, two superconducting magnet beam storage rings, six experimental halls, and a number of support buildings. Accelerated protons, deuterons or heavy ions in counter-rotating beams, each in separate rings, may be brought into collision at five different locations where experiments are conducted. The particle cascade produced by the colliding beams is recorded by various instruments to study nuclear phenomena in detail.

A forward-peaked shower of secondary particles (e.g., neutrons) will be created wherever the beam strikes solid material such as a beam stop. Beam stops are the sinks used to absorb the energy from beams that have completed their utility; they also serve to absorb the secondary radiation, which is produced when the particle beam energy is dissipated. The shower of secondary particles may interact with the soil surrounding the tunnel or below experimental halls, causing a transformation of stable elements into radioactive elements (radionuclides). Radionuclides created via this mechanism include tritium, beryllium-7, carbon-11, nitrogen-13, oxygen-15 and sodium-22.

Radionuclide production in soil is an environmental aspect that could lead to groundwater impacts. Without additional engineering controls, such radionuclides could eventually reach the water table through leaching induced by rainwater percolation. Leaching processes are slow enough that only radionuclides with relatively long half-lives such as tritium ( $t_{1/2} = 12.3$  years) and sodium-22 ( $t_{1/2} = 2.6$  years) are of environmental significance. All other induced radionuclides will decay *in situ*.

### AGS

The AGS and its experimental system are made up of four basic units: the particle injection source (Linac or Tandem), the booster ring, the main synchrotron ring and experimental target areas. For radiation shielding, the tunnel areas are typically first covered with a ten foot layer of native sand and gravel, followed by a one foot layer of compressible Styrofoam, a five foot layer of a special concrete/soil mixture ("soil-crete") and, finally, a six to 15 foot layer of compacted

sand and gravel. This shielding combination reduces the ability of precipitation to infiltrate the soils immediately surrounding the AGS tunnel.

The beam stops are typically made of ilmenite loaded concrete and steel. Ilmenite is a natural mineral,  $\text{FeTiO}_2$ , with a high iron-content. The size of a beam stop is designed such that it entrains the bulk of radioactive atoms created as a result of stopping primary particles and their secondaries. For example, the iron beam stop for the g-2 experiment, is 50×10×10 feet in size, and it sits on a 3-foot thick concrete pad.

As discussed above, secondary particles created near AGS beam targets and stops have the potential to activate soils surrounding the accelerator tunnels or soils underlying target and beam stop areas in the experimental hall areas. Identified areas where soil activation is either confirmed or suspected to occur include: the Linac beam dumps (4), the BLIP-Y, the Building 912 main experiment hall; the AGS Booster Beam Scraper; the former E-20 Beam Catcher; the Building 914 transfer tunnel; the g-2 Target, Beam Stop and VQ12 magnet; the J-10 Beam Stop; the former U-Line Target area; and the H area of the AGS Ring where Slow Extracted Beam (SEB) enters Building 912. (See Figure 3 for a map of the AGS complex and the location areas listed above.) The g-2 experiment, currently shutdown, is documented in a separate Process Assessment, [AGS-579-G2](#). Process Flow Diagram [CAD-580-BMS-01](#) graphically depicts the process inputs and outputs for the various AGS beam stops and scrapers.

## **NSRL**

The NSRL is an extraction system in the booster ring, followed by a beam line, target area and beam stop. A separate Process Assessment is found in [CAD-595-BAF](#). The beam dump is a deeply recessed and well-shielded opening in the Target Room concrete that accepts the remainder of the beam energy after interaction with target material. The dump is about 3 feet of concrete followed by 8.5 feet of steel. The dump is surrounded by soil for additional shielding. This soil will become activated and a cap has been installed to prevent any leachate from contaminating the groundwater. To preclude any potential groundwater contamination, the entire NSRL berm has also been capped.

## **RHIC**

The RHIC superconducting magnets cannot tolerate energy deposition from beam losses. A few millijoules of energy deposited per gram will quench the superconductor. Even small losses will, by design, initiate a beam abort. Consequently, secondary radiation fields, which could result in unwanted radionuclide production, will be minimal. In addition, because the rings store beams for many hours per cycle, the total amount of integrated beam energy generated per year is very small compared to a comparable fixed target accelerator like the AGS. However, RHIC operations are still capable of producing radionuclides in air inside the tunnel and in soil external to the tunnel. Since >99% of all beam energy will normally be deposited at the beam stops and beam collimators, concerns for radionuclide production in soil exist primarily at these discrete locations. Since the beam kickers, which abort the beam into the beam stops, have a small aperture, some beam may also be lost at the location of the kickers.

RHIC beam stops consist of large blocks of steel surrounded by marble, which are designed to absorb particle energy at the end of the beam's useful life. The marble ( $\text{CaCO}_3$ ) walls are in place around the steel to attenuate secondary radiation created during beam absorption and also serves to minimize residual radiation levels in the tunnel (see Figure 1). The beam stops are designed to receive approximately 85% of all beam energy produced by RHIC. They are located at the 10 o'clock position of the ring. Another stop located at the W-Line, which connects the AGS to RHIC, will see much less beam energy because the beam is at the lower RHIC injection energy. Extremely small volumes of activated soil are expected at this location.

RHIC beam collimators are designed to "clean up" the particle beam and act as a limiting aperture by "scraping" out particles, which are not in the desired machine aperture. The collimators are designed to receive approximately 15% of all beam energy produced at RHIC. They are located at the 6, 8 and 10 o'clock positions of the ring.

The environmental aspects of air and soil activation (including groundwater impacts) have been organized into processes labeled "Radionuclide Production in Soil" and "Airborne Radioactivity". Process Flow Diagram [CAD-580-BMS-01](#) graphically depicts the process inputs and outputs for the RHIC Beam Stops and Collimators.



Figure 1 RHIC beam stop surrounded by marble shielding

## **Regulatory Determination of Process Outputs**

### **1.0 Radionuclide Production in Soil**

#### **1.1 AGS and NSRL**

Identified areas where soil activation is either confirmed or suspected to occur include: Linac beam dumps (4), the BLIP-Y where beam is directed from Linac to BLIP, Building 912 (main experiment hall); the Booster Beam Scraper; the E-20 Beam Catcher; Building 914 (transfer tunnel); the g-2 Beam Target and Stop; the g-2 VQ12 magnet which experienced significant beam loss in 1999; J-10 Beam Stop; the former U-Line Target area; the H area of the AGS where SEB is extracted in Building 912; and the NSRL beam dump (see Figure 2). Each is described below.

**Linac Beam Dumps (4) and BLIP-Y** – Recent estimates of the potential soil activation surrounding these beam loss areas indicate that the soils may be activated enough to cause the groundwater to be contaminated above 5% of the DWS if the rainwater infiltrates the berm. Because of the geography and drainage characteristics of this area, rainwater infiltration is not expected to be significant. The BLIP-Y soil area was capped in the summer of 2004 (Figure 2). The remaining Linac activated soils areas are scheduled to be capped in the near future as funds permit.



**Figure 2 Soil cap over BLIP-Y chamber**

**Building 912** - The present target design includes shielding which is likely to significantly reduce the production of additional soil activation. During the earlier years of AGS operation, less shielding was used directly below the target areas (i.e., it consisted of the 1.5 foot thick floor slab). Targets and beam stops located inside this building include stops for the A Line, the B

Line (2 stops), the C Line (2 stops), and the D Line. Stormwater infiltration around the building is controlled by paving and stormwater drainage systems that direct most of the water to recharge basins located to the north of the AGS complex. Therefore, most of the potentially activated soils underlying the beam targets and dumps are protected from surface water infiltration. This building is currently undergoing major decommissioning activities to prepare for future large high-intensity proton experiments.

**Building 914** - Due to beam loss near the extraction (or “kicker”) magnet used to extract Booster beam to AGS, the extraction area of Building 914 is heavily shielded with iron. Since the extraction area is housed in a large building structure, soil activation is limited to the areas below the floor of the building. Water infiltration through potentially activated soils is likely to be minor, because the soils are isolated beneath the floor of the building, and portions of the transfer tunnel are covered with a soil-crete mixture.

**Booster Beam Scraper** - The Booster beam scraper is in the Booster “B” super-period, an area where the interaction of secondary particles and soil surrounding the Booster tunnel may result in production of tritium and sodium-22. In addition to internal shielding, the Booster tunnel was covered with sand derived from the BNL site. A cap was placed over the scraper region to provide protection. The cap is constructed of 20-mil plastic and is covered by soil. If the cap is effective at preventing water from leaching through the activated soils, the radioactivity will be confined to the region outside the Booster tunnel, allowing for the radioactivity to decay in place.

**Booster Beam Dump** – This is a dump kicker and absorber block. It is a 1 meter long steel cylinder surrounding the beam pipe. It has a radial thickness of 19 cm and is shielded by an additional 20 cm of iron to reduce soil activation. It was moved from the D-section of the Booster to the B-section in the Summer of 2002. Both the D-section and B-section dump areas have an impermeable liner to protect groundwater. The old D-section dump soil is still activated and the liner prevents leachate from contaminating the groundwater.

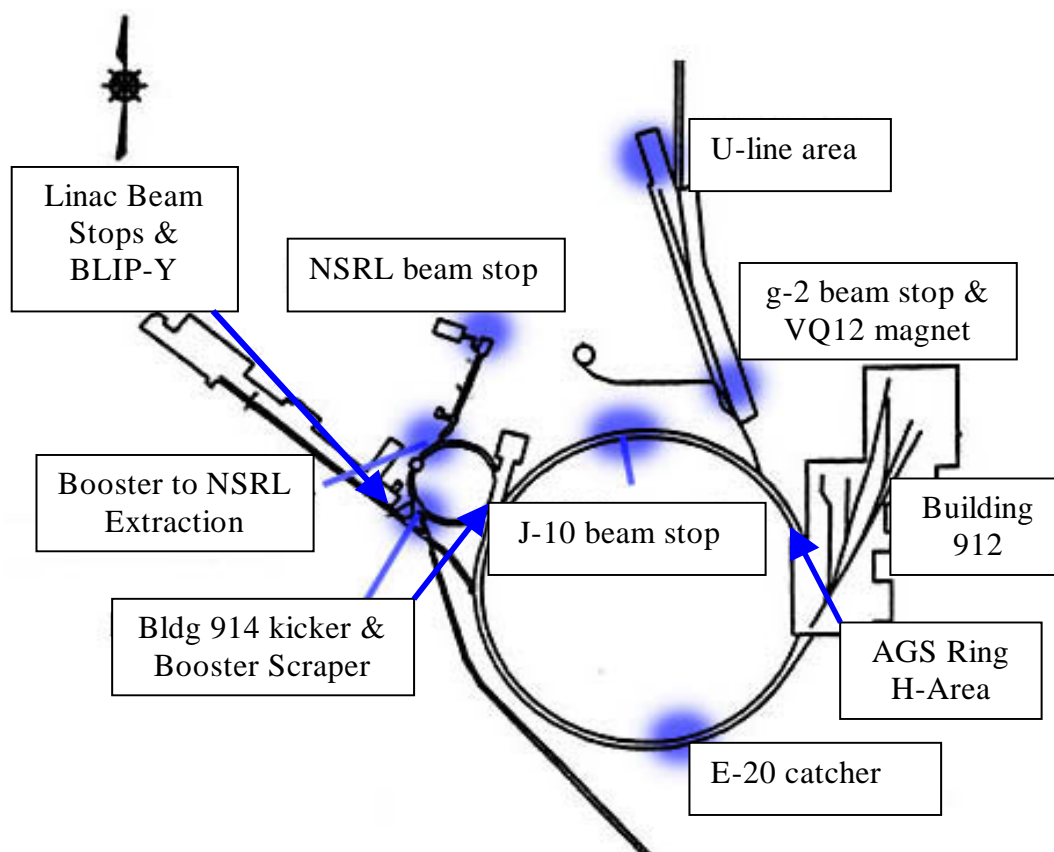
**Booster Extraction to NSRL** – As discussed above, the location of the Booster dump was moved from the Booster D-section to the B-section in the Summer of 2002. The new Booster slow-extraction components for NSRL were placed in the D-section. The old dump area in the D-section remains capped to prevent groundwater contamination from the existing activated soils. Losses from the Booster to NSRL extraction is < 0.2% of the old dump losses, so the existing cap is more than adequate for extraction

**E-20 Beam Catcher** - The E-20 beam catcher was located at the 5 o’clock position of the AGS ring, an area known as the “E” super-period. The E-20 catcher was a minimum aperture area of the AGS ring, used to remove or “scrape” protons that wobbled out of the desired path. The catcher was in use from 1984 to 1999 when it was replaced by the J-10 beam stop at the 12 o’clock position (described below). Like other beam loss areas within the AGS complex, the E-20 Catcher is an area where the soils surrounding the AGS tunnel have become activated through interactions with secondary radiation.

During 1999, tritium and sodium-22 were detected in the groundwater at levels ranging from non-detectable to approximately one-quarter of the federal and state drinking water standard in a permanent monitoring well near the E-20 catcher. The Laboratory installed four temporary wells in January 2000 to further define tritium and sodium-22 concentrations in this area. Detectable levels of each radionuclide were found. The highest concentrations of sodium-22 and tritium were 700 and 40,000 pCi/L, respectively. The drinking water standard for sodium-22 is 400 pCi/L, and the standard for tritium is 20,000 pCi/L. C-AD installed a new concrete cap over the E-20 catcher area to prevent further leaching of activation products in accordance with the cap requirements in SBMS. Well monitoring indicates the concentrations of tritium and sodium-22 are well below the DWS and are continuing to decline due to the effectiveness of the cap.

**J-10 Beam Stop** - The AGS Department has established a new beam stop in the “J” super-period, designated J-10, at the 12 o’clock region of the ring (see location on Figure 2). The J-10 beam stop serves as the preferred repository for any beam that might be lost in the AGS ring, replacing the E-20 catcher. This beam stop will be subject to the same injection, transition, ejection and studies losses, which occurred at the E-20 catcher. Therefore, the same activation products are likely to be produced in the soils surrounding the tunnel adjacent to the J-10 stop. The ability of rainwater to infiltrate potentially activated soils surrounding the J-10 stop is reduced by the presence of a poured concrete roof and a soil-crete cover. However, in an effort to further reduce the potential for surface water to infiltrate activated soils, a gunnite cap has been placed over exposed soil areas overlying the this region.

**Former U-Line Target Area** - The U-Line target area was in use from 1974 through 1986. During its operation, a proton beam from the AGS would first strike a target and the resulting secondary particles would be selected by an arrangement of two magnetic “horns” and collimators immediately downstream of the target. Secondary particles desired for research would be focused by the horns, and other particles would either strike the collimators or be defocused and enter the surrounding shielding. The entire assembly was located in a ground-level tunnel covered with an earthen berm. Internal shielding was stacked around the horns. Although the U-Line target has not been in operation since 1986, the associated tunnel, shielding and overlying soils remain in place.



**Figure 3 AGS Beam Stops and Scrapers and Activated Soil Areas**

The former U-Line target and horns are areas where the interaction of secondary particles with soil surrounding the tunnel resulted in production of tritium and sodium-22. Because the tunnel was not covered by an impermeable cap, the activated soils above and on the sides of the tunnel structure have been exposed to rainwater. The capping of the U-line beam-stop occurred following groundwater monitoring results indicating elevated tritium in the fall of CY 2000. Subsequent well monitoring indicates that the tritium and Na-22 concentrations contained in this plume are well below the DWS and are continuing to decline indicating that the cap is working.

**g-2 Beam Target and Stop** – see [AGS-579-G2](#) for a full description of this experimental area and associated groundwater issues, including the activated soil surrounding the VQ12 magnet. This experiment is no longer used. Since the plume from this release is still active, BNL Long Term Response Actions Group is in the process of producing a Focused Feasibility Study to determine the optimum actions required to mitigate the groundwater contamination using inputs from engineering studies and the desires of the regulators and surrounding community. This study will be published and distributed to all stakeholders in FY 06.

**AGS Ring H-Area** – Reviews of beam loss monitoring data during high-intensity SEB proton running, showed that beam losses were occurring in this area of the AGS ring. This loss does not occur during Fast Extracted Beam (FEB) operations. No SEB running was funded since FY03.

**National Space Radiation Laboratory (NSRL)** – This facility was commissioned with beam in October 2002. At NSRL, there will be activated soils surrounding the beam stop and portions of the target room. A landfill-type geomembrane cover has been installed over the beamline, the target room and, the adjacent beam stop to prevent the infiltration of water through these soils. Routine operations of NSRL commenced in the summer of 2003.

## **1.2 RHIC**

Radionuclides are produced in soils surrounding the RHIC tunnel via the same mechanisms described in the previous section. At RHIC, the only two areas where significant production of radionuclides is expected are at the beam stops (located at 10 o'clock) and the collimators (located at the 6, 8 and 10 o'clock areas). Minor losses can occur at the abort kickers because of their small aperture.

Using the conservative assumption that approximately one-half of all annual precipitation is allowed to leach through the most activated soils, the annual average tritium and sodium-22 concentrations in soil pore water directly below the beam stop areas may reach 170,000 pCi/L and 20,300 pCi/L, respectively. For pore water directly below the collimator areas, annual average tritium and sodium-22 concentrations may reach 39,000 pCi/L and 4,600 pCi/L, respectively. It should be noted that the volume of water at these concentrations would be less than 40 gallons for the beam stops and 120 gallons along the length of the collimator area, annually.

Radionuclides leached from soils near the RHIC beam stops and collimator areas would undergo significant dilution upon entering the water table. Concentrations would be further reduced through radioactive decay and dispersion during transit to the nearest potable water source, in this case, BNL potable supply well #10. The distance between the collimator area and supply well #10 is approximately 3,500 feet, corresponding to a travel time of almost 12 years. Given these considerations, it is unlikely that any RHIC-produced radionuclides would be detectable at well #10 even without further action. However, measures to mitigate radionuclide leaching have been taken and are discussed in the Waste Minimization section.

Waste ID	Waste Description	Determination/Basis	Waste Handling	Corrective Action Required
1.1	Tritium and Sodium-22 production in soil	Radionuclide type and quantity based on computer modeling or direct measurement	None	None

Originally, acceptable levels of radionuclide production in soils were determined according to two criteria:

- (1) Predicted concentrations had to be less than five times the DOE Order 5400.5 Derived Concentration Guides (DCGs). (The DCG is the concentration of a radionuclide in water, which if ingested at a rate of two liters per day for one year, would result in a committed effective dose equivalent of 100 mrem per year.) The Order indicates that  $5 \times$  DCG level is the point at which Best Available Technology (BAT) for controlling liquid effluents should be evaluated.
- (2) DOE Order 5400.5 requires that liquid effluents from DOE activities shall not cause private or public drinking water systems located downstream of facility discharges to exceed the drinking water radiological limits promulgated in 40 CFR Part 141, National Primary Drinking Water Standards.

It is important to note that existing Orders and federal drinking water standards are designed to address the more common problem of controlling radioactive liquid effluent releases to surface waters, and not the direct activation of soils which could lead to groundwater impacts. Under existing DOE regulations, the only requirement which must be satisfied in order to demonstrate compliance is to guarantee that any radionuclides which are produced in soils and subsequently transmitted to groundwater meet the 4 mrem/yr criteria at the point of ingestion. This resulted in a design goal, which allowed for the production of radionuclide concentrations up to 5 DCGs in groundwater at the source. Due to local stakeholder concerns, these design criteria were superseded by Design Practice for Known Beam-Loss Locations in the Accelerator Safety Subject Area of SBMS. This current design practice limits the concentration of accelerator-related radionuclides in groundwater to 5% of applicable drinking water standards at designated points of assessment. This is 1% of the previous design goal from DOE Order 5400.5. The points of assessment for the new design practice are groundwater-monitoring wells placed as close to the potential source as is physically practical (see Section IV for further discussion).

## 2.0 Airborne Radioactivity

### 2.1 AGS

In the experimental areas, trace amounts of short-lived airborne radioactivity are observed near target-cave gates, although there is no forced-air moving system. Typical gross beta activity concentrations in air near target-caves are about  $1 \times 10^{-8}$  microCi/cm<sup>3</sup> or less. A total immersion dose rate from airborne radioactivity near a gate is estimated to be about 0.2 mrem/hr with  $2 \times 10^{13}$  protons (20 TP) per second on target. Although several radionuclides are present, most of this dose is attributable to oxygen-15 ( $t_{1/2} = 2.1$  min), nitrogen-13 ( $t_{1/2} = 10$  min) and carbon-11 ( $t_{1/2} = 20$  min). Other air activation products generated by this mechanism include tritium, beryllium-7, oxygen-14 and argon-41. Airborne activity as indicated by detectable gross beta activity is not measurable more than a few meters beyond the target-cave gates. Airborne radionuclides released from AGS cooling water towers are discussed separately in [AGS-004-CWS](#). Note that while air activation products are generated in the AGS and Booster tunnels, neither the AGS nor the Booster are ventilated to open air during operations with beam, thus preventing atmospheric release.

Though the release of radionuclides to the atmosphere from this source is extremely small, and of no dose consequence to members of the public, Subpart H of the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) recognizes no *de minimus* for tracking such emissions. Under NESHAPs, all emission sources which could contribute 0.1 mrem/yr or less to the maximally exposed member of the public require only periodic, confirmatory sampling to verify low emissions. C-AD has a formal program in place to satisfy this requirement, see C-A OPM 9.5.12.

### 2.2 NSRL


The NSRL Target Room is continuously ventilated to reduce odors from biological specimens. Since the beam passes through about 28 feet of air, from the end of the vacuum pipe to the beam dump, production of radionuclides in the Target Room air will occur. The Target Room is exhausted to the atmosphere via an elevated stack, which penetrates the berm. The stack is 7.6m above ground level, 0.3m in diameter, and the nominal flow rate is 535 cfm. The annual dose to the maximally exposed individual (MEI) is only about  $10^{-5}$  mrem/yr. This is ten thousand times less than the trigger point (0.1 mrem/yr) for the NESHAPS permitting process and for a continuous stack monitoring facility. Periodic grab samples will be taken to confirm low emissions. C-AD has a formal program in place to satisfy this requirement, see C-A OPM 9.5.12.

### 2.3 RHIC

Operation of RHIC is expected to result in the production of airborne radionuclides in all six sextants of the tunnel due to small beam losses. All such radionuclides could potentially be released through tunnel penetrations. Estimates of radionuclide production within the tunnel have been conservatively calculated assuming that the machine may eventually operate at four times current Design Intensity. Also, it is assumed that 100% of the tunnel air is exhausted during

operations with beam. In reality, this will not occur; a much smaller fraction will be released caused by a small amount of natural air circulation. Using conservative annual release rates, and further assuming that all radionuclides are released from the sextant closest to local public areas, the maximum effective dose equivalent for a member of the public is projected to be equal to 0.016 mrem/yr. The dose limit set forth under NESHAPs is 10 mrem/yr.

In 1988, prior to the final promulgation of the radionuclide NESHAPs, an Application for Construction/Modification was submitted to EPA in anticipation of eventual RHIC operations. Under current NESHAPs regulations, this would not be required, since only those air emissions sources, which have a public dose potential of at least 0.1 mrem/yr, need file an application. However, the application was granted in February 1989. The NESHAPs construction approval number for RHIC is BNL-388-01. By similar logic, an Application for Construction/Modification was submitted to EPA for the AGS Booster. The Booster was also granted an approval: BNL-188-01.

Waste ID	Waste Description	Determination/Basis	Waste Handling	Corrective Action Required
	Airborne Radionuclides	Radionuclide type and quantity based on computer modeling	Air activation products may be released to the atmosphere.	None

### III. Waste Minimization, Opportunity for Pollution Prevention

#### Radionuclide Production in Soil

To address local stakeholders' desire that the greatest possible effort be made to eliminate intentional releases of radionuclides to the environment, BNL has been taking steps to either reduce the amount of radioactivity produced in soils by means of additional shielding, modifying operating procedures to better control beam losses or to prevent the leaching of these materials to groundwater by installing landfill-type caps in key locations.

At RHIC, caps made of geomembrane fabric have been installed over the beam stop and collimator areas. In 2001 it was decided to extend the existing beam stop cap over the RHIC beam abort kickers to ensure that any activation in the soil is prevented from affecting groundwater. This was accomplished in the summer of 2002. The design goal for these caps is to prevent the infiltration of precipitation through the most highly activated soils surrounding the tunnel, and thereby prevent the leaching of radionuclides to groundwater. Twelve dedicated groundwater-monitoring wells have been installed at the beam stop and collimator areas to verify the long-term effectiveness of the geomembrane caps.

At the AGS complex, various caps have been installed to prevent rainwater from infiltrating planned or existing soil activation areas. These include: (1) a plastic and soil-crete cap at the C-A-OPM 14.13 (Y)

Booster Beam Scraper, (2) a plastic cap over the E-20 Catcher, (3) a gunnite cap over the new J-10 Beam Stop, (4) a geomembrane cap over the Booster Applications Facility target room, beam stop and berm, (5) additional covers at the g-2 beam target area (see Process Assessment [AGS-579-G2](#) for details), and (6) a gunnite cap over the U beam stop. An extensive array of groundwater wells is in place to monitor the effectiveness of these caps (see Figure 3 for cap locations).

As previously noted, the Linac beam stops (4) and BLIP-Y will be capped when funding permits, and the AGS H area is currently being evaluated to determine if a cap is required to prevent the groundwater from being contaminated above 5% of the DWS.

### Airborne Radioactivity

Activation of air near beam lines and in target caves at AGS is minimized by ensuring that beam travel through air is minimized. This is done by restricting beam travel to evacuated tubes or by using helium-filled bags in areas where the beam must leave a beam tube.

Significant in-place decay of short-lived air activation products occurs within AGS target caves and within the RHIC tunnel before radionuclides reach the outside atmosphere. There are no HVAC units in AGS beam line and target caves, and the RHIC HVAC was designed without make-up; that is, air is merely recirculated in the RHIC tunnel.

The NSRL target room is the only C-A facility with a forced air exhaust stack. The Target Room is continuously ventilated to reduce odors from biological specimens. The activity released from the stack is so small that no action is required to reduce these emissions.

During the initial effort of baselining the Collider-Accelerator Department processes for Pollution Prevention and Waste Minimization Opportunities each waste, effluent, and emission was evaluated to determine if there were opportunities to reduce either the volume or toxicity of the waste stream. Consideration was given to substitute raw materials with less toxic or less hazardous materials, process changes, reuse or recycling of materials and/or wastes, and other initiatives. These actions are documented in this section of the original process evaluation. Action taken on each of the Pollution Prevention and Waste Minimization items identified can be found in the Environmental Services Division's PEP Database. Further identification of Pollution Prevention and Waste Minimization Opportunities will be made during an annual assessment of C-A processes. If any Pollution Prevention and Waste Minimization Opportunities are identified they will be forwarded to the Environmental Services Division for tracking through the PEP Database.

## **IV. Assessment Prevention and Control**

The presence of physical barriers to prevent radionuclide leaching will minimize groundwater impacts. Periodic air sampling in the RHIC tunnel, NSRL Target Room exhaust stack air discharge and AGS target caves/gates can be used to verify that radionuclide emissions remain

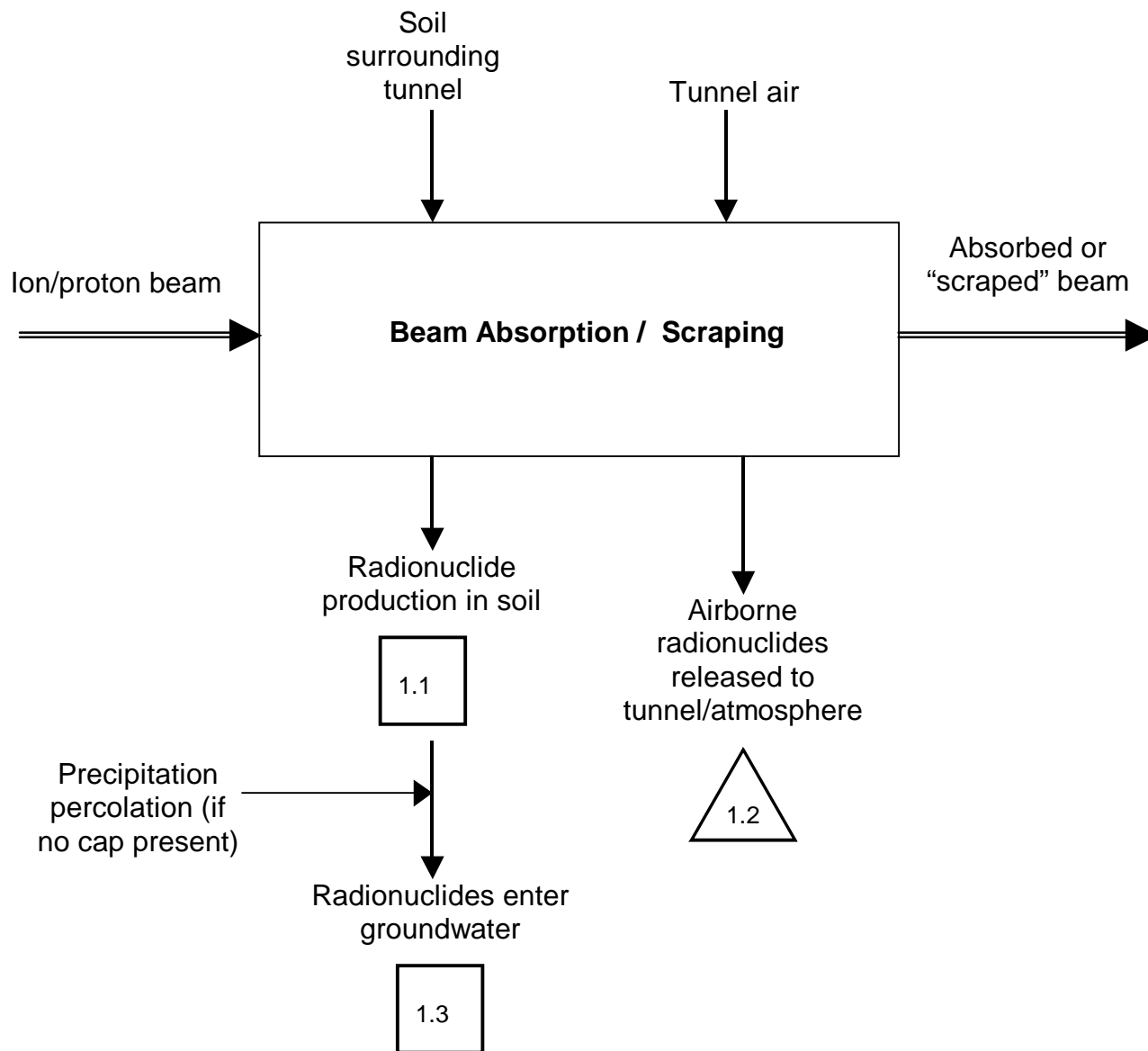
extremely low. A program for collecting samples for compliance purposes has been formalized into the C-AD Operations and Procedures Manual (OPM 9.5.12).

Many of the activated soil areas throughout the complex are monitored by analyzing the actual soil just outside the beam tunnel wall or removable soil samples (RSS). The RSS are located at the inner wall of the tunnels near loss points (see [C-A OPM 9.5.15](#)). The samples are checked by gamma scan for the sodium-22 concentration in pCi/g of soil. The calculation from the SBMS Accelerator Safety Subject Area, Design [Practice for Known Beam Loss Locations](#) is used to determine the potential pCi/L of H-3 and Na-22 in leachate to determine if capping the area is required. At the present time, the RHIC collimators at the 6 o'clock area are uncapped and the RSSs are used to verify that this configuration continues to be acceptable.

During the initial effort of baselining the Collider-Accelerator Department Assessment, Prevention, and Control (APC) Measures operations, experiments, and waste that have the potential for equipment malfunction, deterioration, or operator error, and discharges or emissions that may cause or lead to releases of hazardous waste or pollutants to the environment or that potentially pose a threat to human health or the environment were described. A thorough assessment of these operations was made to determine: if engineering controls were needed to control hazards; where documented standard operating procedures needed to be developed; where routine, objective, self-inspections by department supervision and trained staff needed to be conducted and documented; and where any other vulnerability needed to be further evaluated. These actions are documented in this section of the original process evaluation. Action taken on each of the Assessment, Prevention and Control Measures can be found in the Environmental Services Division's PEP Database. Further identification of Assessment, Prevention and Control Measures will be made during an annual assessment of C-A processes. If any Assessment, Prevention and Control Measures are identified they will be forwarded to the Environmental Services Division for tracking through the PEP Database.

Areas that are currently scheduled to be capped in order to prevent contamination of the groundwater above 5% of the DWS are the Linac beam stops and the AGS H area before significant high-intensity proton beam restarts. In addition a Focused Feasability Study is being prepared by the BNL to determine the best option to mitigate the g-2 tritiated groundwater plume. C-A is assisting ERD with this study and will implement the recommendations of the selected option.

C-AD is currently working with E&WMSD to map all known soil activation areas throughout the C-A Complex. The results of this work are being posted at [http://www.rhichome.bnl.gov/AGS/Accel/SND/soil\\_activation\\_areas.htm](http://www.rhichome.bnl.gov/AGS/Accel/SND/soil_activation_areas.htm) as they are completed.



BROOKHAVEN NATIONAL LABORATORY  
PROCESS ASSESSMENT PROGRAM  
**C-AD – Beam Stops and Collimators**  
**Process Flow Diagram**

**CAD-580-BMS-01**